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SVENSKA SKIFFEROLJE AKTIEBOLAGET, ÖREBRO

A process for the production of shale oil through electrothermal pyrolysis directly in shale rock

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It has been suggested in patents Nos. 121,737 and 123,136 that shale rock be heated by means of electric heating elements inserted into said rock, so that pyrolysis is produced. The oil gases then formed as well as other gases are taken out through special outlet channels in the rock for collection and utilization by means of condensation and other processes. Among other things, the invention refers to a way of implementing this heating process, so that the energy required for the same is obtained at a lower cost than is presently possible, and so that in other words the production method for the oil is reduced. Another purpose is to achieve a heating process in which the shale rock serves as an accumulator for inexpensive electrical energy, so to speak, in which energy is thus preserved in the form of heat and . . . [illegible] and benefits a pyrolysis carried out on a later occasion. An additional purpose is to

prepare the shale rock in advance, so that the leakage of the products extracted during the pyrolysis is actively prevented.

These and other purposes as well as qualities that characterize the invention in other ways will be more thoroughly described in the following, in which one example of a way of implementing the invention has been illustrated schematically in the enclosed drawing. The drawing shows: Figure 1, a vertical cross section of a shale rock; and Figures 2 and 3, two diagrams. 10, in the drawing, indicates an oil-bearing stratum of shale on which a stratum of lime 12 and possible a layer of soil 14 may be overlaid. Into channels that are vertically drilled a great number of electric heating elements 16 are inserted, arranged to emit their heat to the shale layer 10. Reference is made to the above-mentioned patents for a more thorough description of the design and installation of these heating elements as well as the outlet channels. The heating elements 16 are by means of branch wires 18 connected to the electric power line system 20 through which low-tension current is fed into the heating elements. As is also apparent from these patents, the heating of the shale rock is carried out in such a manner that a heat front, wandering horizontally, is created. Its direction is indicated with 22 in Figure 1. According to the invention the heating of the shale rock is divided into two stages, a preheating and a subsequent heating to the final temperature, named the pyrolysis heating below. When heating the shale an oil-forming pyrolysis occurs at a temperature that exceeds 250°C, and oil gases and other hydrocarbon gases start to be formed to a noticeable degree only near 300°. Between 300° and 400°, for example, the most active pyrolysis takes place, that is within this area mainly all quantities of oil and gas are formed, that are yielded during the electrothermal oil production. The

preheating is now carried out in an area of the shale rock that is limited by the dotted lines 24, 26 in the example of implementation shown on the drawing, at which the heating elements that exist in this area are connected to the power line 20. The temperature then gradually rises through the successive connection of new rows of heating elements 16 according to curve 30 in Figure 2, the abscissa of which indicates the surface extent of the shale field according to Figure 1 in the direction of the heat front, while its ordinate indicates the temperature in the shale rock. During the preheating the shale rock is heated to a temperature corresponding to line 32 in Figure 2, where no substantial pyrolysis has started yet, for example 240° to 280°. The pyrolysis heating is conducted within a part of the rock limited by the lines 34, 36 which is separated from the preheated part. During the pyrolysis heating the temperature of the rock increases by stages according to curve 38 to the final temperature according to line 40, which can amount to 360° to 420°. After a certain lapse of time the preheating can have reached up to curve 30^1 and the pyrolysis heating to curve 38^1. There are consequently two separate heating zones in the shale rock, which wander forwards in the same direction.

In the example above approximately two-thirds of the required quantity of heat is supplied to the shale rock during the preheating, and only about one-third of the same during the pyrolysis heating. While the preheating can be pursued periodically, the pyrolysis heating is carried out as continuously as possible, which has an advantageous effect on the production. As an example, we will assume that the preheating only takes place during half the year. It may be assumed that the same quantity of energy is supplied to a heating element per time unit at all times. Since two-thirds of the total quantity of heat is

supplied during the preheating, it is obvious that during this four times as many heating elements shall be connected as during the pyrolysis heating, which means that twice the amount of heating is supplied in half the time. The speed of movement of the preheating front limited by lines 24, 26 becomes simultaneously double the size of the speed of movement of the pyrolysis front between lines 34, 36. From this it is understood that between the two heating fronts there will be a part of the shale rock of a varying length. This part has reached the temperature level according to line 32, that is, has been brought up to the temperature at which the pyrolysis can be started. When the preheating is interrupted the distance between the lines 26 and 34 is reduced; when the preheating has been started again this distance is increased.

This interruption in the heat supply to the shale rock, after the same has reached the temperature level 32, brings about a number of very important advantages. While heat is being supplied to the heating element 16, the shale rock around the same gets a different temperature, in that this falls in the direction away from the element according to curve 42 in Figure 3. In this figure the abscissa that corresponds to curve 42 is indicated with 44. After the electrical energy has been disconnected, the temperature is evened out according to curve 46. Because of the interval between the two heating periods the shale rock will thus show a more complete equalization of the temperature within the rock part that has been heated. A shale rock has a coefficient of thermal expansion of about . . . [illegible]. With the distance of 2 to 3 m that occurs between the different heating elements 16 and with the temperature differences that are shown in curve 42 in Figure 3 (for example 200°) the expansions of different parts created

by the heating become in this connection highly variable within the shale rock, at which very uneven thermal stresses develop within the same. Generally, however, there is a tendency towards thermal enlargement in a horizontal direction brought about by the general heating of the rock. This heat enlargement tends to compress all vertical cracks that exist in the shale rock and therefore acts in a sealing manner on these cracks. However, during the preheating period on one side in the rock partial zones appear, that want to compress the above-mentioned cracks and on the other side other zones where such a compression is prevented. At the evening-out of the temperature during the interval between the two heating periods the compression of existing cracks becomes more general and therefore more effective. The gases produced during pyrolysis heating taking undesirable paths is thus counteracted to a very great extent because of interruption in the heat supply. With electrothermal extraction of oil the invention further brings about advantages in the final financial result. The preheating period can with advantage be implemented during times when cheap hydroelectric power is available in relative abundance. The invention then offers an advantageous alternative to the electric steam-boilers where, as is well known, electrical energy is used for the steam production. The pyrolysis heating is carried out with a relatively even supply of electrical energy. The heat supply required for this can suitably constitute a smaller part of the entire quantity of supplied heat according to the above.

In the electrothermal production of shale oil partly oil-forming gases are created, which through condensation are preserved in liquid form, partly also other gaseous hydrocarbons as well as hydrogen gas, which only with great difficulty can be condensed at low temperatures, and which therefore are called incondensable gases below. These gases generally constitute

half the quantity of all extracted hydrocarbons and have approximately the same effective combustion value as the liquid hydrocarbons. For each liter of produced oil about 1 m^3 of gas is thus simultaneously obtained. This gas is an excellent fuel and, if used properly, has great commercial value, equivalent to that of the oil, but with regard to the distribution and the sales opportunities is not as easy to handle as the oil. An extensive gas pipe network and great construction costs will thus accompany the distribution of gas, and if all gas were to be distributed from a place where, for example, 200,000 m^3 of oil are produced yearly, considerable difficulties arise. To the extent that the components present in the gas cannot be taken care of on the spot (sulfur, etc.) the same is best used instead as fuel in a power station that generates electrical energy which according to the invention possibly alternatively with other supplied energy, for example from hydroelectric power, is applied to the pyrolysis heating of the shale rock. If the shale rock is then heated according to the invention in the above-described manner a periodic preheating of the shale rock is obtained on the one side, while on the other side an evenly or almost evenly progressing pyrolysis heating can be arranged through the supply of electrical energy from the gas-fired power station. The pyrolysis heating can thus, through a suitable adjustment of the temperature to which the rock during the preheating is heated, be carried out without additional external energy in the form of hydroelectric power. The pyrolysis heating then proceeds continuously independently of the preheating that can be arranged periodically, adapted for example according to the supply of surplus power from the hydroelectric power stations. In this manner the steam power station obviously get a continuous and, if so desired, even load and of particular

importance, the pyrolysis proceeds along an even and undisturbed course, irrespective of the market prospects of the hydroelectric power. However, the pyrolysis heating can be carried on with different intensities during different periods or seasons, respectively, because different numbers of heating elements are simultaneously connected to the power network. In countries of, for example, the size and nature of Sweden, the invention makes it possible that under all conditions surplus energy or what is known as secondary power from the hydroelectric power stations can find use in a financially advantageous manner in the production of liquid fuel. Through the preheating the shale rock then constitutes an accumulator that preserves energy from hydroelectric power in the form of heat which then at a much later time can be utilized for the final oil extraction if so desired.

According to the invention the steam power station can be fired either with gas from the pyrolysis process only, or it can be fired with other fuels, depending on the market prospects on each separate occasion. In this way the gas can be easy to sell during certain periods, as for example during the winter for the gas supply of the cities. During the summer when such a gas consumption is smaller the steam power station can be fired with the gas only or with a suitable combination of gas and other fuels. According to the invention the incondensable gas can thus also be utilized in a particularly favorable manner, at which the combination of on the one hand a periodically heated shalé rock where the preheating is in progress, accumulates and utilizes the available cheap hydroelectric power, while on the other hand at the same time the pyrolysis heating can be carried out with only the incondensable gas produced through the pyrolysis, at which this use of the gas also can occur periodically in interaction with the use of the gas for other purposes. In such a case it is also conceivable

to vary the intensity of the pyrolysis heating by altering the number of live elements 16 in order to adjust the quantities of oil and gas, respectively, produced per time unit and the consumption of electric power according to price situations. A periodic operation of the preheating can generally be conceived to be carried out synchronously with the seasons. In the summer there is as a rule a surplus of electric power available, for example, while at the same time during this season the gas consumption in the cities, for example, decreases to less than half of that during the winter. Because of the preheating energy accumulated during the summer a steam power station can in the winter, according to the invention, therefore contribute to the electric power supply by firing with other fuels than the gas, while simultaneously the pyrolysis gas produced during the same time is used in the gas distribution to the cities, and there fetches a higher price than as a steam-boiler fuel. According to the invention a production of shale crude-oil, for example, is made possible is an electrothermal way from the relatively oil-poor Swedish shales so economically satisfactorily that this oil can often financially compete with imported oils.

The gas-fired power station can of course be equipped with steam turbines or gas tubines or other modern motors for thermal power.

The size of the Swedish shale deposits allow that according to the invention very large thermal power stations (. . . [illegible] MW and more) will be put to use. According to the invention these power stations can at the same time be kept available as a national reserve for hydroelectric power as well as for absorbing peak loads in the national power network. During peak loads a power station can thus alternatively be used, either for shale oil production, or as a national reserve power station during dry years when oil production can possibly be set aside.

Patent Claims

1. A process for the production of shale oil through electrothermal pyrolysis directly in shale rock, characterized by the fact that two heating zones are created in the shale rock, one of which is preheated, while already preheated shale rock is subjected to pyrolysis heating in the other zone, and that electric heat is supplied to both, however, under different conditions with regard to time, in such a manner that a preheated part of rock of a horizontally changing width is present between the preheating zone and the pyrolysis heating zone.

2. A process according to claim 1, characterized by the fact that a zone in the shale rock is first preheated by means of electric heat, supplied discontinuously, while another zone of the shale rock, which has been preheated at an earlier point in time, is heated to a higher temperature at which pyrolysis takes place by supplied electric heat, also during periods when the supply of electric heat to the first mentioned zone of the shale rock is interrupted.

3. A process according to claim 1 or 2, characterized by the fact that the electric heat required for the pyrolysis heating of the shale rock is taken from a power station, at least partly fired with pyrolysis gases, produced through the pyrolysis process in the rock.

4. A process according to one of the previous claims, characterized by the shale rock being heated over a greater temperature interval during the preheating than during the pyrolysis heating.

5. A process according to one of the previous claims, char terized by the preheating being carried out with a supply of greater quantities of electricity per time unit than the pyrolysis heating.

Fig.1.

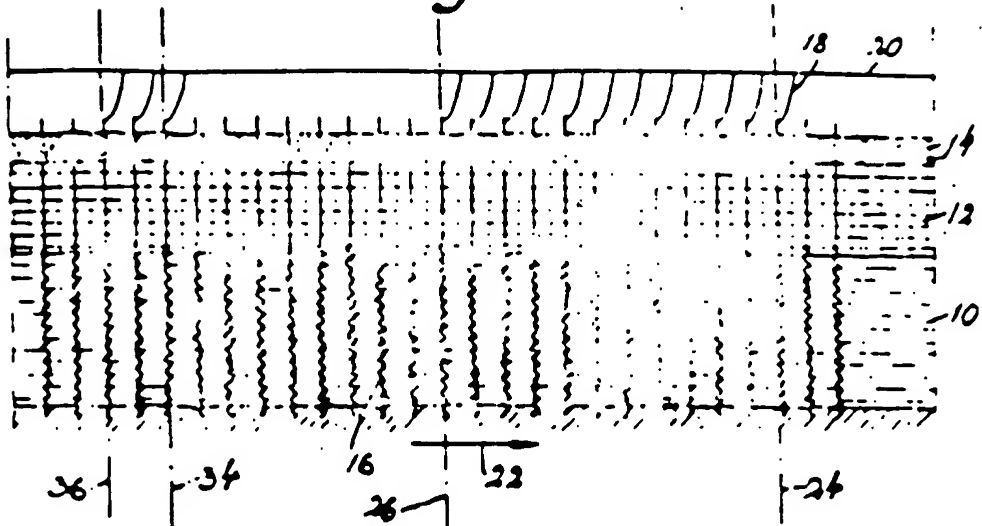

Fig.2.

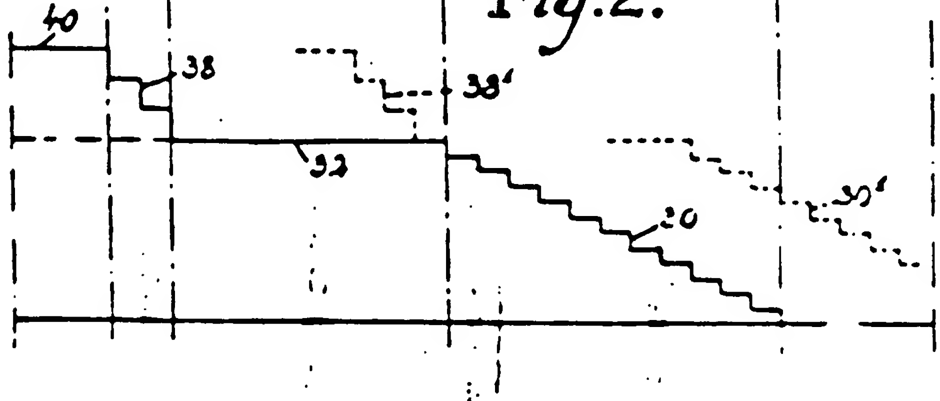

Fig.3.